Atmospheric Physics II

4b. Determine the thermal wind and its relationship to temperature advection.

Thermal wind vector (V_{th})

- A calculated wind (nonexistent/theoretical) found by computing the vector difference of geostrophic winds at two levels for the same location.
- The equation below relates the vertical shear of the geostrophic wind to the horizontal temperature gradient.
- NOTE: Nothing actually moves in the direction of V_{th}.

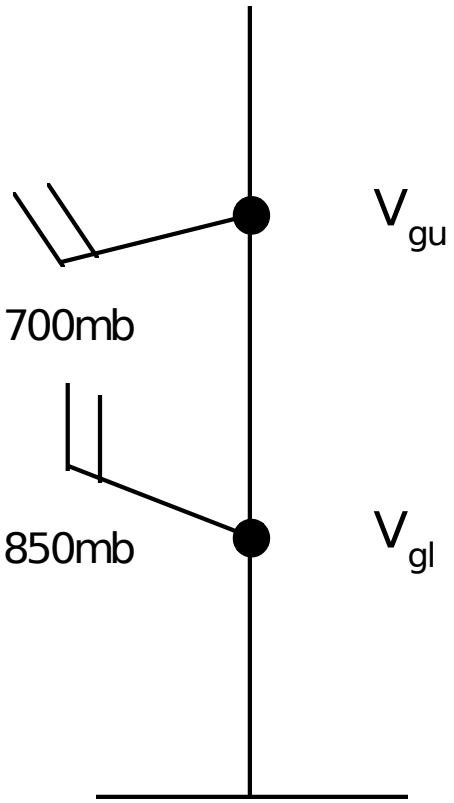
V_{gu} = upper wind, V_{gl}= lower wind.

$$V_{th} = V_{gu} - V_{gl}$$

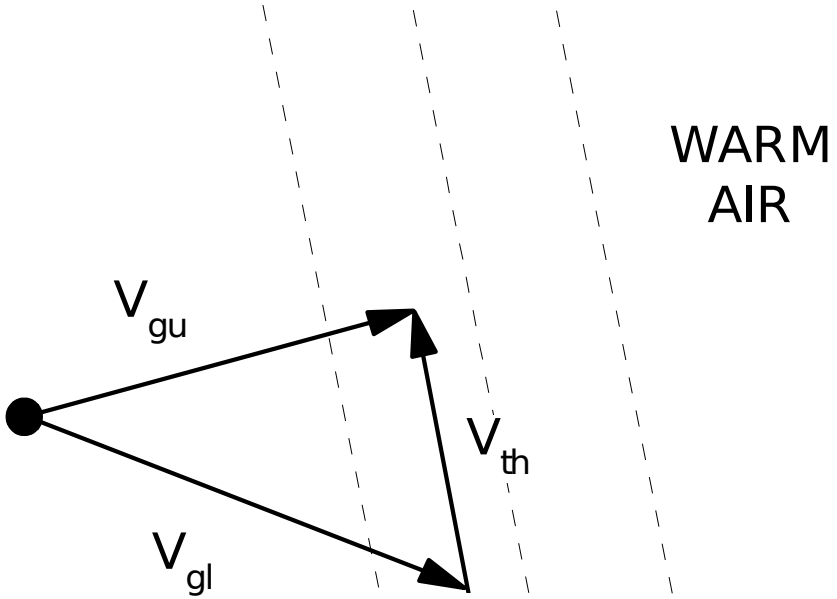
Thermal wind vector (V_{th})

- The magnitude, or length, of the thermal wind vector is proportional to the strength of the mean temperature gradient within the layer (thickness packing).
- The vector direction indicates the orientation of thickness lines with cold air on the left and warmer air to the right. (With the thermal wind to your back, colder temperature is to your left.)

$$V_{th} = V_{gu} - V_{gl}$$



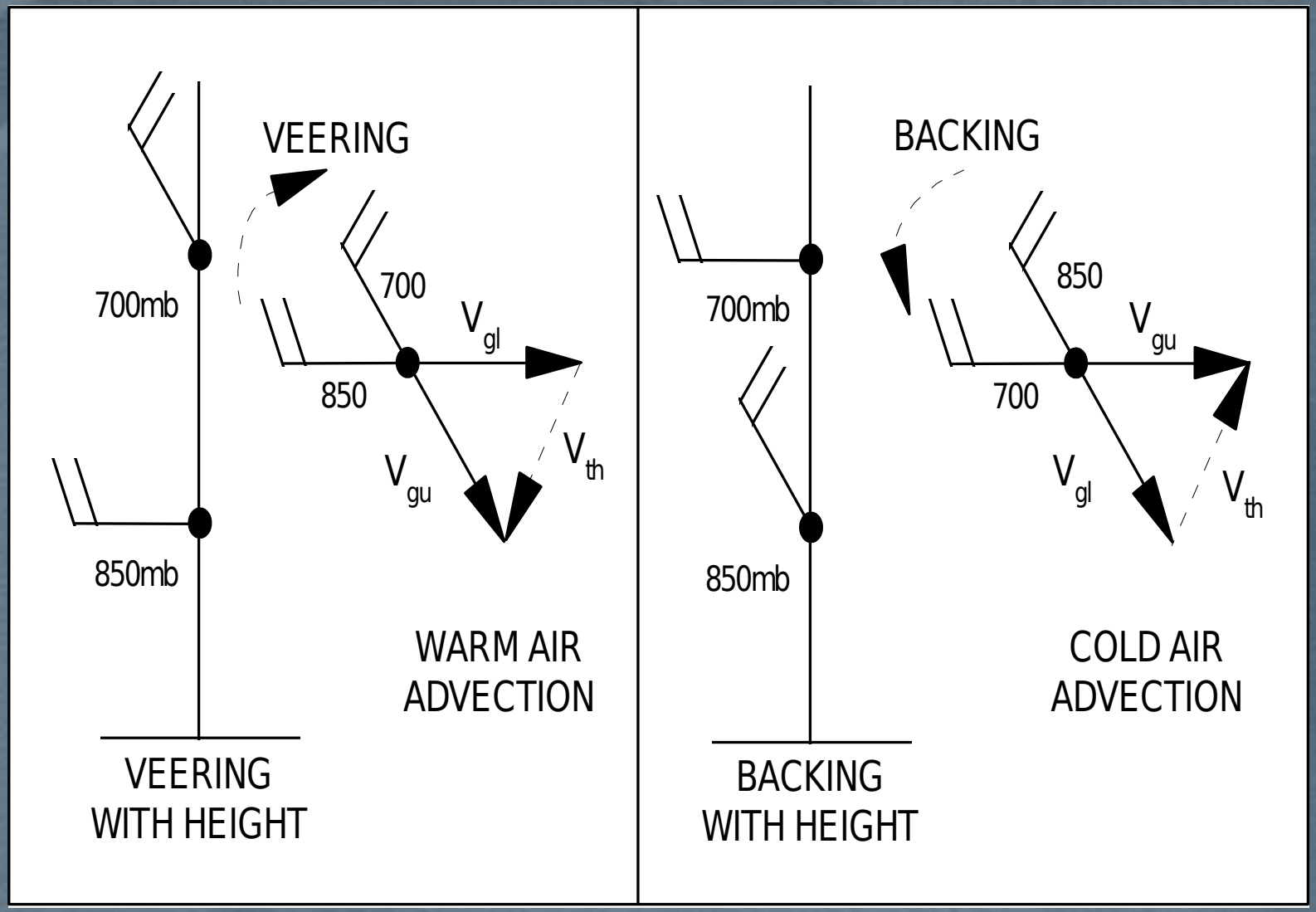
SKEW-T



THICKNESS LINES

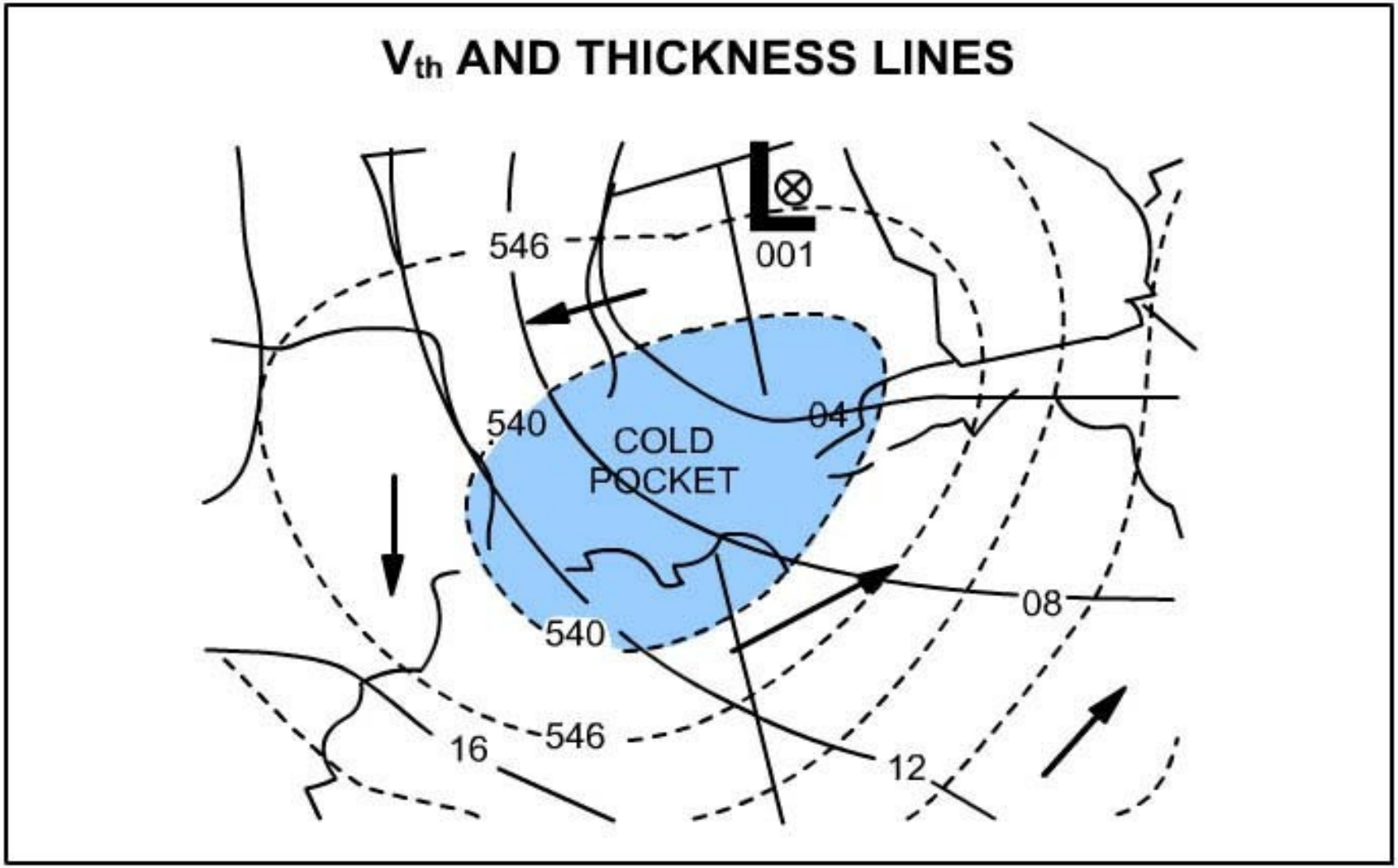
Thermal wind vector (V_{th})

- In many cases, the observed winds (on a Skew-T) above the boundary level (i.e., above the gradient level) are approximately geostrophic), and are commonly used to calculate $\mathbf{V_{th}}$.
- The meaning of $\mathbf{V_{th}}$
  - Winds veering with height indicate warm air advection (WAA) in that layer.
  - Winds backing with height indicate cold air advection (CAA) in that layer.


VEERING
700mb
700
V_{gl}
850
V_{gu}
V_{th}
850mb
WARM AIR
ADVECTION
VEERING
WITH HEIGHT
BACKING
700mb
850
V_{gu}
700
V_{gl}
V_{th}
850mb
COLD AIR
ADVECTION
BACKING
WITH HEIGHT

Thermal wind vector (V_{th})

- Characteristics
  - The thermal wind vector is oriented parallel to thickness lines just as winds are oriented parallel to isobars.
  - Colder air and lower thickness values are to the left, while warmer air and higher thickness values are to the right of the thermal wind vector.


Vth AND THICKNESS LINES
546
001
540
COLD
POCKET
04
08
540
546
16
12

Thermal wind vector (V_{th})

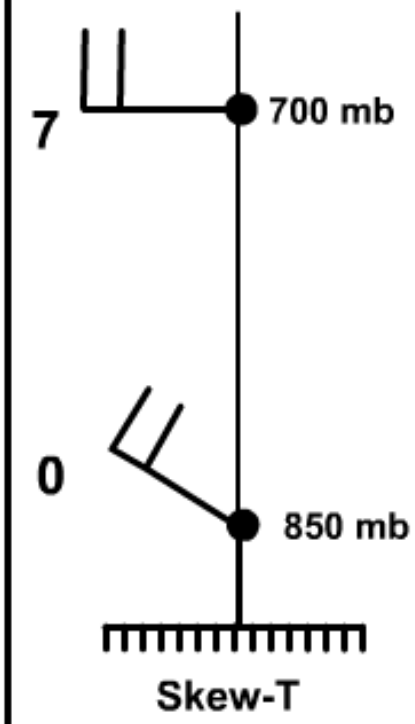
- As a rule of thumb, use winds above 3,000 ft AGL for finding the thermal wind (above friction-influenced planetary boundary layer level).

Thermal wind (V_{th}) application

- Two uses
  - Advection Trends
    - Recall: use vector addition divided by 2 to find mean wind (V) for the layer.
    - This represents magnitude and direction of advection.

$$V = \frac{V_{gu} + V_{gl}}{2}$$

STRENGTH OF THERMAL ADVECTION



MEAN ADVECTION FOR THE LAYER

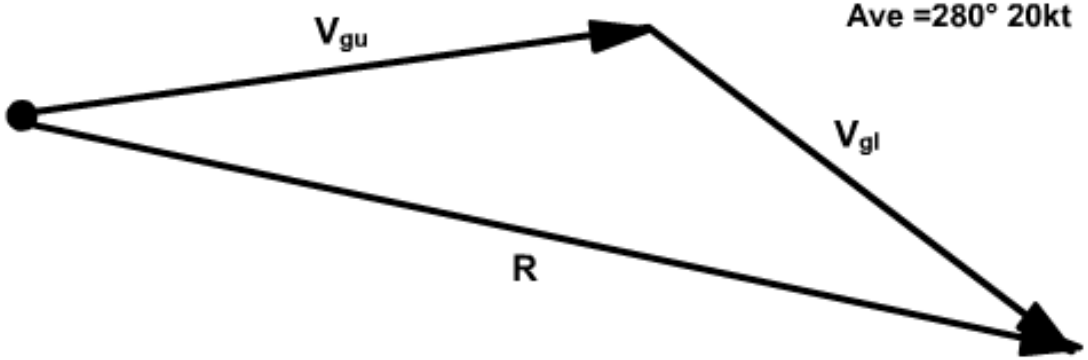
$$V = \frac{V_{gu} + V_{gl}}{2}$$

V_{gu} =270° 25kt

V_{gl} =300° 15kt

R =280° 40kt

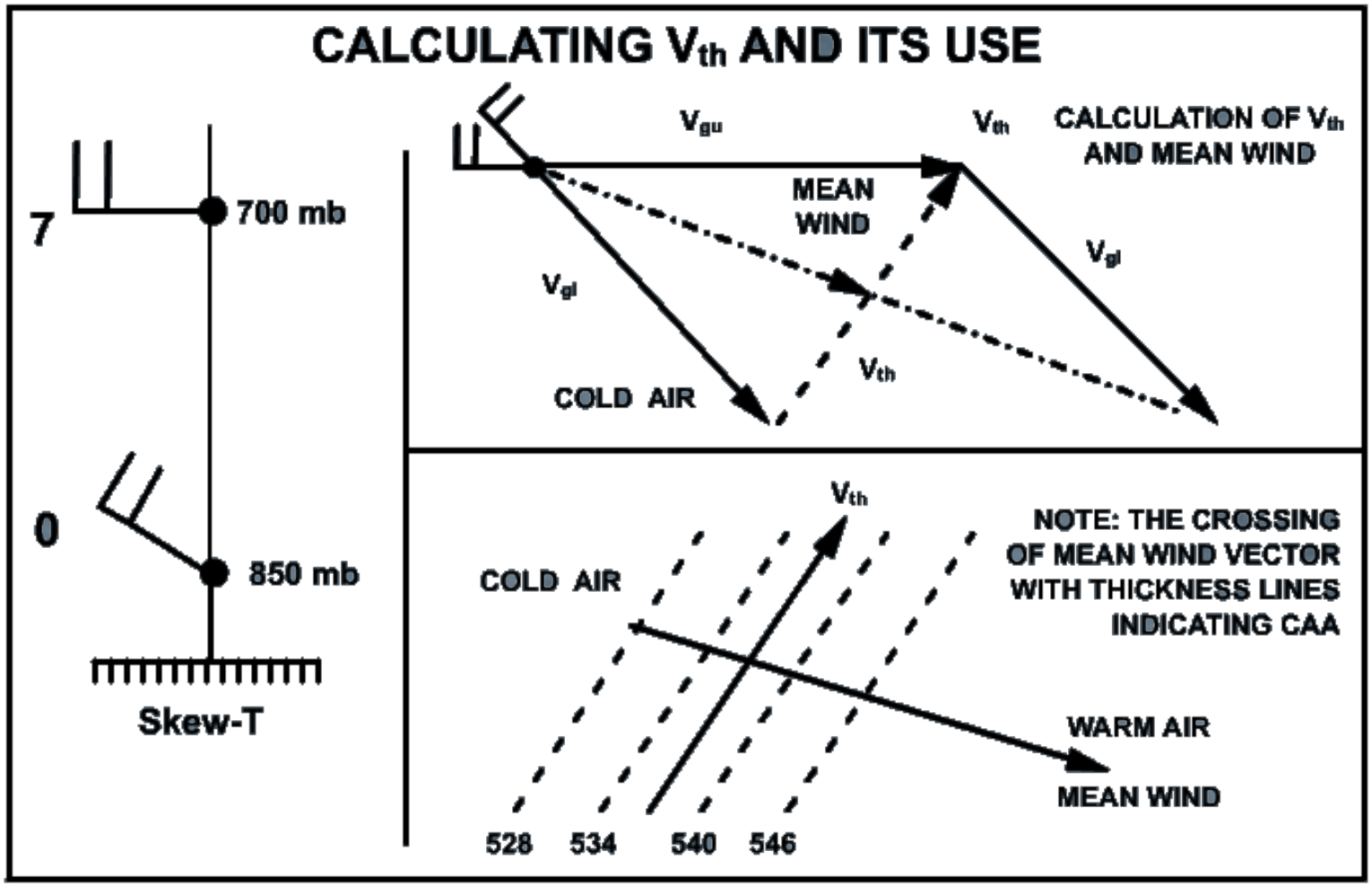
Ave =280° 20kt



$$\text{MEAN WIND} = \frac{V_{gu} + V_{gl}}{2}$$

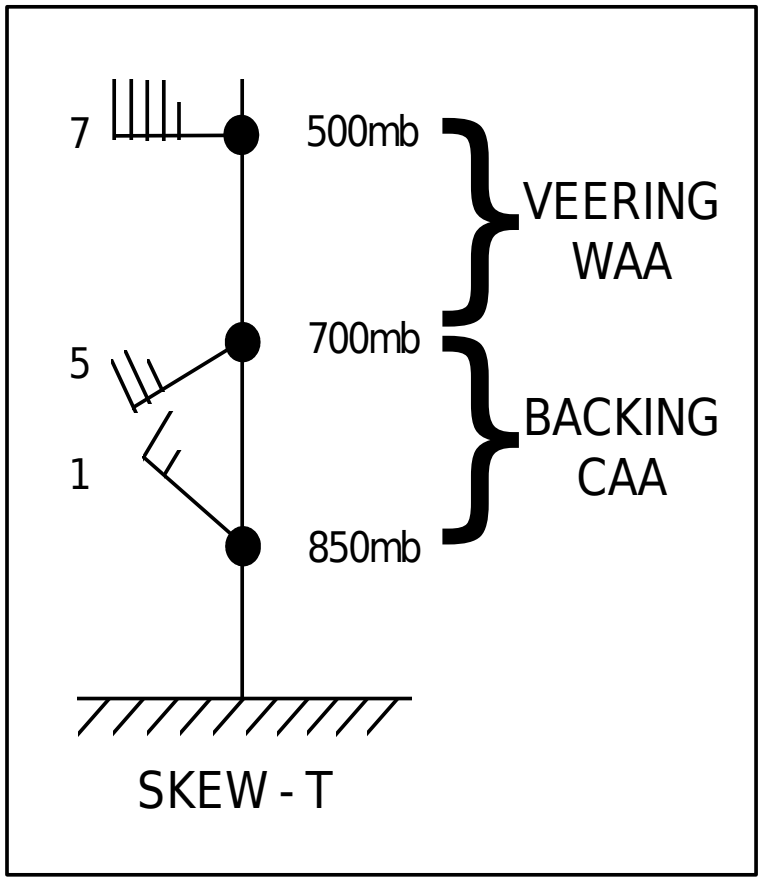
Thermal wind ($\mathbf{V_{th}}$) application

- The type of thermal advection can be determined by combining the thermal wind vector ($\mathbf{V_{th}}$) with the mean wind vector ($\mathbf{V}$) for a layer.
  - First find the $\mathbf{V_{th}}$ by vector subtraction.
  - Next find the mean wind vector by vector addition.

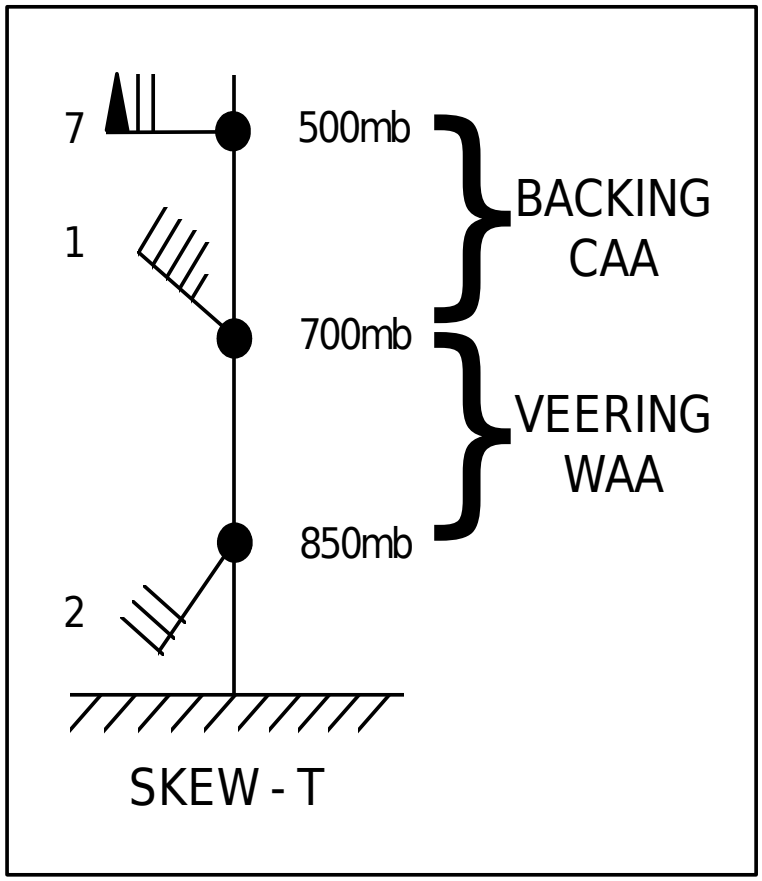

CALCULATING Vth AND ITS USE
7
700 mb
0
850 mb
Skew-T
Vgu
Vth
CALCULATION OF Vth
AND MEAN WIND
MEAN
WIND
Vgl
Vgl
Vth
COLD AIR
Vth
COLD AIR
NOTE: THE CROSSING
OF MEAN WIND VECTOR
WITH THICKNESS LINES
INDICATING CAA
WARM AIR
MEAN WIND
528
534
540
546

Thermal wind (V_{th}) application

- Two uses
  - Stability
    - WAA over CAA indicates increasing stability, because
      - The density of the air increases at the surface and decreases aloft.
      - The temperature lapse rate decreases.
    - CAA over WAA indicates decreasing stability, because
      - The density of the air decreases at the surface and increases aloft
      - The temperature lapse rate increases..
    - Use your soundings, if available, or mandatory levels from constant pressure charts.



SKEW-T, CAA under WAA
Increased Stability



SKEW-T, WAA under CAA
Decreased Stability

Thermal wind (V_{th}) application

- Mesoscale
  - The concept of thermal wind is extremely useful in single station analysis and forecasting.
  - With one Skew-T sounding you can determine the type and magnitude of advection between all levels.

Thermal wind ($\mathbf{V_{th}}$) application

- Synoptic Scale
  - Since **V** (the mean wind vector) represents the orientation and strength of the mean temperature gradient in a layer, the $\mathbf{V_{th}}$ will be oriented parallel to the thickness contours.
  - In most operational weather offices the type and strength of advection is determined from the 1000-500 mb thickness chart.
  - This chart is derived by subtracting the heights of the 1000-mb level from the height of the 500-mb level.
  - The use of this chart in determining advection is covered in the next objective.

- APPLICATION: Assign Review Exercise in WB-100
- EVALUATION: Administer and evaluate Appraisal 104b. Give the written Test at the end of the unit.